In the name of Allah

Spectrum Sensing Based on Cyclostationarity

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Content

- Cognitive radio and its demands
- Introduction to Cyclostationarity
- Detection based on Cyclostationarity
- Conclusion

Cognitive Radio

- For What
- Primary versus secondary user
- Spectrum sensing
  - interference
  - Using idle channels

Spectrum Sensing

- Different methods
  - Matched filter
  - Energy detector
  - Cyclostationary method
  - …

Spectrum Sensing…

- Need for doing well in low SNRs
- Differentiate between noise, interference & signal
- Using one detector
- Does not require signal information
- Robustness against noise power uncertainty

Spectrum Sensing…

"the sensing tiger team of the IEEE 802.22 group specified the requirements of the spectrum sensing of ATSC DTV signals: the miss detection probability (*PMD)* should not exceed 0.1 subject to a 0.1 probability of false alarm (*PFA) when the SNR is -20.8 dB"*

Cyclostationarity

- Hand made signals are Cyclostationary!
- Noise assumed to be stationary
- So:

  we can differentiate between them

Cyclostationarity…

- Definition:

$$\mu_x(t) = \mu_x(t + T_0) \qquad \forall t$$

$$R_x(t, \tau) = R_x(t + T_0, \tau) \qquad \forall t, \tau$$

- So:

$$R_x(t, \tau) = \sum_\alpha R_x^\alpha(\tau) e^{j2\pi\alpha t}$$

$$R_x^\alpha(\tau) = 1/T_0 \int_{-T_0/2}^{+T_0/2} R_x(t, \tau) e^{-j2\pi\alpha t} dt$$

Cyclostationarity…

- In more general case: (Almost Cyclostationary)

$$R_x(t,\tau) = \sum_{\alpha \in A} R_x^{\alpha}(\tau) e^{j2\pi\alpha t}$$

$$R_x^{\alpha}(\tau) = \lim_{T_0 \to \infty} 1/T_0 \int_{-T_0/2}^{+T_0/2} R_x(t,\tau) e^{-j2\pi\alpha t} dt$$

- A is the set of freq. for which:

$$R_x^{\alpha}(\tau) \neq 0$$

Cyclostationarity…

- Then we have:

$$S_x^\alpha(f) = \int_{-\infty}^{+\infty} R_x^\alpha(\tau) e^{-j2\pi\alpha\tau} d\tau$$

- We call $\boldsymbol{R_x^\alpha(\tau)}$ "Cyclic auto-correlation function", $\boldsymbol{S_x^\alpha(f)}$ "Spectral Correlation Density function (SCD)" or "Cyclic spectrum", and $\boldsymbol{\alpha}$ "Cycle frequency"

Detection

- Estimation of Cyclic auto-correlation function :

$$\widehat{R}_x^\alpha(\tau) = \frac{1}{T}\sum_{t=0}^{T-1} x(t)x(t+\tau)e^{-j2\pi\alpha t} = R_x^\alpha(\tau) + \varepsilon_x^\alpha(\tau)$$

- Do it for several delay, so:

$$\widehat{R}_x^\alpha = [\mathrm{Re}\{\widehat{R}_x^\alpha(\tau_1)\}, \dots, \mathrm{Re}\{\widehat{R}_x^\alpha(\tau_N)\},$$

$$\mathrm{Im}\{\widehat{R}_x^\alpha(\tau_1)\}, \dots, \mathrm{Im}\{\widehat{R}_x^\alpha(\tau_N)\}]$$

Detection…

- Estimate $R_x^{\alpha}(\tau)$ for several cycle freq.
- hypothesis test:

$$H_0: \forall \tau_i\ , i = 1, \ldots, N, \forall \alpha \in A: \hat{R}_x^{\alpha} = \varepsilon_x^{\alpha}$$

$$H_1: for\ some\ \alpha \in A\ \exists \tau_i\ , i = 1, \ldots, N: \hat{R}_x^{\alpha} = R_x^{\alpha} + \varepsilon_x^{\alpha}$$

Detection…

- Choose an appropriate statistic
- Choose a threshold
- Calculate the statistic according to SCD
- So

SCD should be estimated

Some Note

- Rate of False Alarm is very important
  - CFAR methods
- Different method for estimating SCD
- Better performance by cooperative spec. sensing
- Better performance by using multiple antennas

Major Challenge

- High complexity
  - SCD has two dimensions
  - Large size of FFT
- Time consuming
  - Miss the opportunities
- Calculating SCD in special freq. and cycle freq.

Conclusion

- Detection based on Cyclostationarity is a solution for CR
- But…
- It has its problems
- There is a lot of work to do!

Any Questions?